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ABSTRACT

The effect of the amount of prior knowledge on the long-term retrieval of information is examined. In two studies, seventh and eighth grade students of average or above average reading ability learned passages to simulate materials from history textbooks (factual), from reading textbooks (narrative), and from science textbooks (conceptual). Students studied passages for 45 seconds, 90 seconds, or 3 minutes depending upon whether the passage was at a high, medium, or low linkage level (i.e., prior knowledge level), respectively. During each test period, students said back what they could remember from the passage and the experimenter gave feedback. The criterion for learning was all but one proposition correct. Students free recalled the passages immediately after learning, and after four weeks. Students' retrospective reports were filled with links to prior knowledge, many of their errors appeared to include partial retrieval of propositions, and the prior knowledge structures surrounding higher prior knowledge passages had more alternate retrieval pathways. In a third study, the conditions of the recall test were identical to those already described except for changes to group testing and to a one-week interval. Although images did not affect recall, prior related knowledge did. (RL)

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Prior Knowledge in the Long-Term Recall of Information

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Summary

In two studies, 7th and 8th grade students learned passages for which they had either high, medium, or low prior related knowledge. One-week or one-month later they free recalled the passages. Degree of prior knowledge had a significant positive effect on the amount of correctly recalled propositions. In a third study the images value of the passage and the prior related knowledge value were independently manipulated. Images did not affect the one-week recall of propositions but prior related knowledge did. The results are discussed in light of an alternate retrieval pathways interpretation.

Prior Knowledge in the Long-Term Recall

of Information

In these studies we were interested in examining the role of prior knowledge in retrieval. There are studies of the role of prior knowledge in comprehension (cf. Bransford & Johnson, 1974) and there are studies of the role of prior knowledge in reconstructive recall (cf. Bartlett, 1932; Spiro, 1977); but there seem to be few studies of the role of prior knowledge in reproductive memory for information. Since reproductive memory is conceptually distinct from both comprehension and reconstruction this previous work cannot be relied on to answer the question "what is the role of prior knowledge in retrieval?"

Underwood and Richardson (1956), although they didn't deal with meaningful discourse, did study the relationship between prior knowledge and long-term reproductive recall. They found no relationship between prior knowledge (measured by meaningfulness) and retrieval of lists, even after controlling for original learning. Based on these and related results, the claim was made that the only important variable for long term recall was the degree of original learning.

Since the Underwood and Richardson study was conducted, however, there have been major conceptual advances that cause one to question the validity of their claim within the domain of connected discourse. Specifically, the notions of John R. Anderson (1976), and Collins and Loftus (1975) with respect to retrieval from long term memory suggest that the nature of the memory structure surrounding to-be-retrieved

information is critical for retrieval even when information is equally reproducible immediately following learning. The richer the interconnections between to-be-retrieved information and other parts of the knowledge structure, the greater the probability of retrieval. The amount of prior knowledge one possesses related to to-be-retrieved information should be a relatively good index of the richness of interconnections between to-be-retrieved information and other knowledge simply because the more relevant prior knowledge one has, the more potential interconnections there are.

Thus the major purpose of these studies was to examine the effect of amount of prior knowledge on the long term retrieval of information. Our measure of prior knowledge was a proposition-level analog of the meaningfulness measure used in the Underwood and Richardson (1956) study. In all the studies reported here subjects learned passages for which they possessed varying levels of prior knowledge to a criterion of all but one proposition correct. As has been pointed out by Underwood (1964), the procedure of learning to an 80-90% criterion prevents overlearning and is probably the best way to equate for original learning. Subjects recalled the learned passages one to four weeks after learning. The main data of interest were the number of correct propositions recalled. We used passages of a variety of forms and content, and subjects of various ability levels so that the generality of the results could be demonstrated.

Study I

Subjects. Fifty-four seventh and eighth grade students of average or above average reading ability (mean grade level score = 11th grade, 3 months on the California Test of Basic Skills) participated in the

study. The participants received six dollars for two one-hour sessions.

Design. The experimental design was a 3 x 2 design, with one within-subject factor (prior knowledge -- high, medium, or low) and one between-subject factor (retention interval -- 11 minutes or 4 weeks). Nested within this design was a Latin-square design which controlled for passage type (factual, narrative, or conceptual) and order of presentation across the three levels of prior knowledge.

Materials. The passages that students learned were written to simulate materials from history textbooks (factual), from reading textbooks (narrative), and from science textbooks (conceptual). Within each of these passage types, three sets of three passages each were written to have identical syntax and word counts but to differ in the amount of prior related knowledge. Table 1 shows one passage set.

Insert Table 1 about here

There was a total of twenty-seven passages, each five to seven sentences long. Table 2 shows the topic of each passage. The three different types of passages (factual, narrative, and conceptual) were chosen to be representative of the entire domain of prose material which students encounter in school. Narrative passages described a person and some actions in a story-telling manner. Factual passages described a particular person, place or event, either fictional or non-fictional, and simulated history, biography, or geography texts. Conceptual passages defined and described a class of objects or relation-

ships in a manner similar to science or social science texts or technical writing within the humanities.

Insert Table 2 about here

The procedures for developing prior related knowledge norms for the 27 passages are described in detail in Gagné, Bell, and Yarbrough (1980). The norms were established using 182 seventh and eighth grade students with average or above average reading scores on the Gates-McGuinitie Reading Achievement Test. These subjects generated as many sentences as they could that connected something they already knew to something from each sentence in the passages. For example, for the passage sentence "Chocolate cakes are rich . . ." a typical response was "I like to eat chocolate cakes." Subjects had two minutes to generate responses to each passage sentence. Approximately twenty students generated responses for each passage and the average number of responses formed the prior knowledge (linkage) score for that passage.

The linkage scores ranged from 5.14 to 29.95, with an average of 16.70 sentences generated per passage. The mean linkage score for the passages representing high, medium, and low levels of prior related knowledge, respectively, was 25.58, 17.05, and 7.40. Analyses of variance revealed no differences in linkage as a function of passage type or passage set.

Procedure. Each subject came to a campus laboratory and learned three passages, one of each passage type (factual, narrative, and conceptual) and one each at high, medium, or low linkage levels. The order of learning of passages of different forms and linkage levels

was counterbalanced across subjects, using a Latin-square design.

A study-test procedure was used for learning. Subjects studied passages for 45 seconds, 1 ½ minutes, or 3 minutes depending upon whether the passage was at a high, medium, or low linkage level, respectively. The different study times were determined in a pilot study to result in roughly equal numbers of study-test trials per passage.

Prior to the first study trial, the experimenter asked the subject a question based on each proposition in the passage about to be learned. Then the experimenter read the passage outloud and asked the subject to say any words she or he had difficulty pronouncing. Lastly the subject was asked the same questions again, but this time was allowed to refer to the passage while answering the questions. The purpose of this procedure was twofold. First, asking the questions beforehand assured us that relatively few passage propositions (less than 1%) were known prior to the experiment. Second, it encouraged meaningful processing of the passages.

Subjects were allowed to learn the passages using any approach that seemed normal to them, e.g. reading aloud, studying silently, etc. During each test period, subjects said back what they could remember from the passage and the experimenter gave feedback, informing the subjects of errors that had been made and of those parts of the passage that still had to be learned. Synonym substitutions were accepted as correct. The criterion for learning was all but one proposition correct (passages were all 5, 6, or 7 propositions in length and length was equal across levels of prior knowledge). The definition of propositions in the learning task was the same as that used to score the

recall protocols and will be described in a subsequent section. The choice of a criterion of all but one proposition correct was based on Underwood's (1964) suggestion that the amount of original learning can be equated for only when the possibility of differential overlearning is avoided, i.e. when the learning task is uniformly interrupted at a level somewhat below mastery.

Immediately after learning, students who had been assigned to the immediate recall condition were given answer sheets with the titles of the passages and asked to write down as much as they could remember. Subjects in the 4 week recall group were scheduled for a second visit in four weeks and told only that they would rate additional passages on how interesting they were. At the second session, they performed a recall task identical to that of the immediate recall group and then rated some passages. They were given the choice of not doing the task but all subjects chose to do it.

All participants recalled the passages in the order in which they were learned. (For the immediate recall group this resulted in an average delay of 11 minutes between learning and recall.) They were given a blank sheet of paper with only the title of the passage at the top and asked to write down everything they could remember from the passage. The experimenter provided no additional recall cues but did assist in spelling words that subjects could pronounce but not spell. After the subject had finished, the experimenter instructed him or her to read what had been written once more and try to complete sentences and write down any additional sentences or words that came to mind. Then the experimenter gave the subject a sheet of paper

with the title of the next passage that had been learned and continued in the same fashion until all three passages had been recalled.

For subjects in the four week condition, experimenters asked about retention interval rehearsal. They asked subjects if they had thought about any of the three passages, if they had repeated any of the passages or any parts of the passages to anyone and, if so, how much and how many times, and what the nature of situation was in which they thought of or repeated parts of the passages. The amount of repitition for each passage was quantified and used as a measure of rehearsal in the data analysis.

Scoring Procedure. Our main interest was in correct recall of propositions. A proposition was defined as a subject-verb-object relationship. In the few cases where the verb had no object, a subject-verb relationship constituted a proposition. In cases where there was a compound verb or compound subject, two propositions were possible. This definition of propositions is most sensitive to recall of independent clauses. Dependent clauses and adjectival phrases are not counted as propositions as they are in Kintsch's scoring system (Kintsch, 1974; Turner and Greene, in press). Our reason for defining propositions the way we did is that it simplified the monitoring process during learning. Remember that the learning criterion was all but one proposition correct. With a more complex definition of a proposition, the reliability of monitoring for this criterion would have decreased.

The recall protocols were scored objectively for number of correctly recalled propositions. During three two-hour training sessions, the

scorers refined the scoring procedure until everyone agreed on identical scores for 30 protocols chosen at random. As an additional control over interscorer reliability, each scored equal numbers of passages from each linkage level.

Results

Passage Type and Order of Learning. Preliminary analyses of variance of the effects of passage type and order of learning on propositional recall revealed no significant effects, $F(2,102) = .05$ and $F(2,102) = .09$, respectively. Therefore, these variables were dropped in further analyses.

Success in Equating for Original Learning. Although the procedure called for stopping learning at the point at which a subject successfully recalled all but one proposition correct, there could nevertheless have been a systematic bias due to linkage. This is because some subjects jumped, in one study-test trial, from recall of less than all but one proposition to recall of all propositions. If this happened more often for high linkage passages, then the attempt to equate for original learning would not have been successful. Therefore, an analysis of variance was performed on the number of propositions recalled on the last learning trial. No significant effect due to linkage was found, $F(2,102) = 1.63$. Thus it appears that the experimental procedure successfully equated for degree of original learning.

The Effect of Linkage. In order to investigate the effect of prior related knowledge (linkage level) on number of correctly recalled propositions, each retention interval condition was analyzed using a one-

way repeated measures analysis of variance with linkage level being a within-subjects factor. No effect of linkage was obtained in the immediate recall condition, $F(2,52) = 1.73$, but a significant effect of linkage was found in the four week recall condition, $F(2,52) = 3.23$, $p < .05$. The average number of correctly recalled propositions for passages having high, medium, and low linkage values, respectively, was 1.7, .93, and 1.44. Scheffé tests revealed that .93 differed from the other two means.

The high level of recall for the low linkage passages was unexpected. However, we suspected that these passages, due to their novelty, had been rehearsed more in the retention interval and that this differential rehearsal explained their memorability. To examine this possibility, a one-way repeated measures analysis of variance was performed on rehearsal scores. This analysis revealed a significant effect of linkage, $F(2,52) = 5.18$, $p < .01$. Reported rehearsal of passages with low linkage was greater ($M = 1.18$) than for passages with medium ($M = .74$) or high ($M = .70$) linkage.

Because of the differential rehearsal of low linkage passages an analysis of covariance was conducted using rehearsal as the covariate. (The assumption of homogeneity of regression was met.) A significant effect of linkage was found, $F(2,51) = 4.07$, $p < .05$. The adjusted mean number of correctly recalled propositions for passages with high, medium, and low linkage values, respectively, was 1.85, 1.04, and 1.19. (These means are shown in Table 3, along with the means obtained from Study 2.) Scheffé tests revealed that while the recall from high linkage

passages differed from the recall from both medium and low linkage passages, recall from the low and medium passages did not differ. Thus, rehearsal did appear to account for the unexpectedly high performance of the low linkage group. When rehearsal effects are statistically removed, the results indicate that prior knowledge has a beneficial effect on the long-term recall of propositions.

Insert Table 3 about here

Study 2

The purpose of Study 2 was to replicate Study 1 while being sensitive to potential inadequacies of that study. Since Study 1 had used subjects with unusually high reading grade level scores, participants for Study 2 were selected from only average reading ability groups. Secondly, the low linkage level was dropped because passages at this level were (1) very difficult and sometimes impossible for good readers to learn, (2) were differentially rehearsed in the retention interval, and (3) did not represent the kind of difficulty level one would expect in textbook material. Moreover, since the analyses performed in Study 1 indicated that it was possible to generalize across passage types, the number of passages used in Study 2 was reduced from 27 to 4. Finally,

since the differential rehearsal of passages by individual participants seemed to be due to a contrast effect in learning passages of three different linkage levels, each participant in Study 2 learned passages from only one linkage level, either high or medium.

Subjects. The subjects were 40 seventh and eighth grade students of average reading ability (based on national norms).

Design. The design was a 2 x 2 design with one between-subject factor (linkage level -- high or medium) and one within-subject factor (passage type -- factual or conceptual). Only long-term recall was measured in this study, the assumption being that the last performance during learning served as an immediate recall measure.

Materials. The materials were the high and medium linkage passages from one conceptual and one factual passage set (see Table 4 for linkage values) which had been used in Study 1.

Insert Table 4 about here

Procedure. Experimenters traveled to the schools and were each provided with quiet rooms where they supervised equal numbers of students in each condition. Each participant was randomly assigned to either the high or the medium linkage condition and learned two passages, one each from the conceptual and the factual set. Order of learning was balanced in the design and randomly assigned to subjects. The same prequestions as in Study 1 were asked and the same study-test procedure for learning was used.

One week later, students returned for an unanticipated recall test.

They were informed that they could choose not to take the test, but none so chose. The entire group of students who participated in the study in any given school took the test together. Other than the change to group testing and the change from a 4 to 1 week recall interval, the conditions of the recall test were identical to those described in Study 1. After subjects finished writing down all they could remember, they filled out a detailed questionnaire concerning how often they had thought about each passage, how many times they had told someone of each of the passages, and how many times they had repeated parts or all of each passage to themselves or to someone else. These answers were quantified and used as a measure of rehearsal. Finally subjects were given a full explanation of the study along with helpful hints on how to remember things.

The recall protocols were scored by an experienced scorer in the same fashion as those scored in the first study.

Results

Rehearsal. In order to investigate the effects of passage type and linkage level on rehearsal, a two-way ANOVA with passage type the within-subjects factor and linkage level the between-subjects factor was computed. No significant differences were found between reported rehearsal of high linkage and medium linkage passages, $F(1,39) = .92$ nor were significant differences found between narrative and factual passages, $F(1,39) = 1.35$.

Recall. A two-way ANOVA on propositional recall scores revealed no significant effect for passage type, $F(1,39) = 1.03$, nor for the interaction of passage type and linkage level, $F(1,39) = 1.46$. However,

the effect of linkage level was significant, $F(1,39) = 6.78$, $p < .01$. The high linkage passages ($M = 2.60$) were recalled significantly better than the medium linkage passages ($M = 1.83$). These means are shown in Table 3, along with corresponding means from Study 1.

Thus, in the results found in Study 1 were replicated in Study 2. In both studies, passages of high linkage value were recalled better than passages of medium linkage value. This effect is obtained under conditions where original learning has been equated.

General Discussion of Studies 1 and 2

These first two studies demonstrate an effect of prior knowledge on retrieval. This effect has been shown across a variety of passage types and topics and across a relatively wide range of subject ability levels. How can this effect be explained?

One explanation is that information that is associated with greater prior knowledge is rehearsed more and that this is why it is easier to retrieve. Our results indicate that the premise of this argument is wrong at least under our experimental conditions. In Study 1 high linkage passages were associated with lower amounts of rehearsal and in Study 2 there was no significant effect of linkage on rehearsal. So even though there is a positive relationship between rehearsal and recall, it is not high linkage that stimulates rehearsal. Hence, the positive effect of prior knowledge on recall must be explained independently of the effect of rehearsal on recall.

Another possible explanation is that the results are due to a word frequency effect. Specifically, the higher average frequency of words used in the high linkage passages oiled the output mechanism so

that subjects could perform at a faster pace, leading to greater recall. The premise of this argument is in fact correct. There was a significant relationship between the average word frequency (using Kucera and Francis norms) for a passage and its linkage value, $r = .56$, $p < .005$. However, there is little evidence to support the conclusion of the argument. The part correlation (rehearsal effects partialled out) of word frequency and recall in Study 1 was .20, which was not significant. By contrast, the part correlation of linkage and recall was .51, $p < .005$. Thus, it appears that an explanation that emphasizes the output advantage for more highly practiced words is not supported by the data.

Another explanation cites imagery as the causal variable. The argument based on imagery would say that higher linkage passages are more highly imageable and thus can be either dually encoded (Paivio, 1975) or processed more in parallel (Baddeley, 1976), in either case leading to greater recall. The premise of this argument gets strong support from the data. In a previous study (Gagné, et al., 1980) subjects stated how many images came to mind as they read each passage. This images measure correlated .83 with the linkage measure.

The conclusion of the argument, that imagery facilitates recall, also gets at least reasonable support from the data. For example, as Table 5 shows, in multiple regressions of images and linkage on residual recall scores (after rehearsal effects were removed), 29% of the variance was accounted for by these two variables. However, no matter which variable was entered first, the contribution of the other did not greatly increase the amount of variance accounted for. Thus images and linkage appear to be mostly non-independent. This result makes it

difficult to say whether linkage or images is the real determining factor in retrieval. We therefore conducted another study whose goal was to examine the independent effects on retrieval of images and linkage.

Insert Table 5 about here

Study 3

Subjects. Subjects were seventh and eighth graders of average and above average reading ability. They were paid for participation.

Design. The design was a two group design. Both groups learned the same control passage. In addition, one group learned a passage that differed from the control passage on images but not on linkage value and the other group learned a passage that differed from the control passage on linkage but not on images value. Thus the variables manipulated are images and linkage.

Materials. Three of the passages used in Studies 1 and 2 were used. Some attributes of these passages are shown in Table 6. The first passage in the table, Sigunde, served as a control passage in the sense that all subjects learned and recalled this passage. In addition, half of the subjects learned the passage titled German Chocolate Cakes and half learned the passage titled Zinc Aluminum Alloys. The German Chocolate Cakes passage is not different from Sigunde on the dimension of images. Both stimulated an average of about three images. However, the Cakes passage has a much higher linkage score -- 23.71 versus 15.79 for Sigunde. This is a difference of one standard deviation on the linkage scale.

Insert Table 6 about here

The Zinc Aluminum Alloys passage is similar to Sigunde on prior knowledge (16.73 versus 15.79), but Sigunde has a higher images score -- 3.13 versus only 1.83 for the Alloys passage, or a difference of two standard deviations. The Alloys and Cakes passages were from the same passage set so they had the same syntactical structure. Thus, the two groups each learned a passage that (a) differed from Sigunde on only one of the two dimensions of interest and (b) did not differ on irrelevant dimensions such as passage type and syntax.

Procedure. Each subject learned two passages -- Sigunde and one of the other two passages -- in the same manner and to the same criterion as was used in Studies 1 and 2. Passage order was counterbalanced across groups. After one week, subjects free recalled the passages, and reported rehearsal activities. Protocols were scored for correct propositions in the same manner as in the previous studies.

Results

The difference in number of propositions recalled for Sigunde versus the other passage is the main data if interest. The mean difference between Cakes and Sigunde is .80 while the mean difference between Sigunde and Alloys is -.15. The former difference is reliably different from zero, $t(19) = 2.29$, $p < .05$, while the latter is not.

Discussion

The results suggest that at average levels of linkage, increasing the images value of a passage does not increase its retrievability, while at low-average levels of images, increasing the linkage value of a passage does increase its retrievability. The results are striking because the two passages that differed on linkage differed by only one standard deviation while the two passages that differed on images differed differed by two standard deviations, and yet it was linkage that showed an effect.

These results are not consistent with an imagery explanation for retrieval. Paivio's dual code theory would have predicted better retrieval of higher imagery material due to its being encoded in two forms -- one imaginal and one verbal. This prediction from dual-code theory was not borne out. Baddeley's theory that imagery provides a more efficient processing mode than does sequential processing would predict better retrieval due to this processing advantage. Such was not found. Any imagery theory that predicts a main effect for imagery, in fact, is not supported by the present results.

Additionally, some retrospective self-report data collected in Study 1 fails to support an imagery explanation. In Study 1, after subjects wrote down what they could remember from the passage, we pointed to each sentence in the recall protocol and asked "what made you think of this" or "what was going through your mind when you thought of this?" These questions were intentionally open-ended and not meant to cue any particular type of response. In these reports, there was not a single mention of imagery, pictures, or any other vocabulary suggestive of imaginal processing.

General Discussion

There is an effect of prior knowledge on the long-term recall of information. This effect appears not to be due to the greater original learning, greater rehearsal, higher word frequency or greater images value of the high linkage passages. What function, then, does prior knowledge play in retrieval?

As was suggested in the introduction, prior knowledge may provide alternate retrieval pathways to target information. The assumptions of this explanation, in the context of the present study, are the following (schematically illustrated in Figure 1): Target information that has a great deal of prior knowledge associated with it will be more highly linked to prior knowledge following learning than will target information that has little prior knowledge associated with it. At recall, the title of the passage is the cue that starts spread of activation. In low prior knowledge passages (side A in Figure 1) most of the activation spreads directly to the target propositions. If the links in these propositions are weak, activation won't spread to all the nodes and links in a given proposition and retrieval will fail (activation is represented by the oscillating lines). In the high prior knowledge passages, some of the activation spreads directly to the target propositions while some spreads to prior knowledge related to the target information. If the links in target propositions are weak, direct retrieval may not be possible. However, if the links in the prior information are strong and if these links tend to lead back to target material then activation will spread down these alternate pathways and retrieval of target information will succeed.

Insert Figure 1 about here

In addition to the recall data itself, there are three lines of evidence that support this interpretation -- retrospective self-reports, an analysis of errors, and a mapping of the alternate retrieval pathways in a sample of high versus medium prior knowledge passages. Each of these will be discussed in turn.

Retrospective self-reports. As was previously mentioned, subjects in Study 1 were asked to say what made them think of each sentence they wrote down at recall. Analysis of these responses revealed three major categories: (a) responses that reflect links to prior knowledge (prior knowledge links), (b) responses that reflect links forged during the learning episode (learning episode links), and (c) an I-don't-know response. A typical prior knowledge link was some sort of episodic memory such as "I like stamp-collecting" where the target proposition was "stamp-collecting is a special hobby for Governor Smith." A typical learning episode link was "I remembered that one was the last sentence". A typical I-don't-know response was "It just popped into my mind".

In a random sample of 10 subjects, 58% of the responses were categorized as prior knowledge links, 29% as learning episode links, and 13% as I-don't know's. These data suggest that subjects are using alternate retrieval pathways in searching for target information.

A valid criticism of these reports is that subjects are reporting what the sentence, once recalled, made them think of, rather than what they actually thought of when recalling the sentence. We tried to encourage honesty by reassuring subjects who said they didn't know how they remembered the information that this was an appropriate response and also by tel-

ling all subjects that there was no one correct answer. Nonetheless, we would not put too much faith in these reports taken alone. Along with other evidence, the self-reports seem more compelling.

Analysis of errors. Errors were defined as any propositions that did not meet the criteria for correct propositions -- that is, they were propositions that did not have all the major constituents correct: subject, verb, and object.

The errors of the twenty-seven subjects in the four week recall group in Study 1 were analysed. Errors were categorized as being either slot-filling or inferences. Inferences included elaborations, which added detail or extended the meaning of the passage, and integrations, which made explicit some implicit connections among passage propositions. Inferences constituted 63% of the total errors.

Slot-filling errors constituted the other 37% of the errors. In slot-filling errors, at least two major constituents (e.g. subject and verb; verb and object) of the target proposition were correctly recalled, but one major constituent was incorrect. The incorrect constituent could be categorized as coming from another part of the passage or from prior knowledge. For example in the Cakes passage, two of the sentences are "Cakes that are made with German cocoas often have a rich taste" and "The light texture of chocolate cakes is often produced by the number of eggs." If a subject recalled "The light texture of chocolate cakes is often produced by cocoa," this error would be counted as slot-filling from other parts of the passage. If, on the other hand, a subject recalled "The light texture of chocolate cakes is produced by baking soda" this error would be counted as slot-filling from prior knowledge. In either case it seems clear that the subject is starting with a partially recalled proposition.

Slot-filling errors suggest some sort of spreading activation plus reconstruction type of process. It is as if the subject recalls through spread-of activation a major portion of a proposition and then uses a generate-and-test strategy to fill in the rest of the proposition. The missing elements can be generated from other passage elements that come to mind or from semantically related elements from prior knowledge. In either case the element is put into the slot in the proposition and the entire proposition is tested for recognition or for sensibility. The details of various retrieval strategies need to be worked out in future studies. The main point here is that a substantial proportion of the errors had the quality of maintaining similarity to passage propositions and hence suggest a spreading activation retrieval mechanism.

Analysis of prior knowledge networks. We have described how the scaling of the linkage value of passages was accomplished by having subjects write down sentences connecting ideas in the target sentences to something they already knew. Ten of the protocols from the scaling study -- five for a high linkage and five for a medium linkage passage -- were used to generate network structures for target passage information and surrounding information.

Figure 2 shows the German Chocolate Cakes passage and a typical network structure surrounding it, while Table 7 shows a translation of this figure into sentences. The target propositions -- propositions 1-5 -- are darker. Other propositions generated in response to target propositions -- propositions 6-15 -- are lighter. (Subjects generated an average of 24 propositions to this passage. This protocol shows fewer than 24 propositions in order to highlight the quality of interconnections rather than the quantity.)

Insert Figure 2 about here

Insert Table 7 about here

As can be seen, some of the generated propositions loop back on target propositions. There are 3 categories of looping propositions. First there are those that connect two or more nodes from the same target proposition. For example, proposition 6 -- "German food is rich" -- connects the 'German' and 'rich' nodes in target proposition 2 -- "Cakes made with German cocoas often have a rich taste". Second there are looping propositions that con ect one or more nodes from two different target propositions. For example, proposition 7, "I like the taste of eggs," connects target proposition 2 "Cakes made with German cocoas often have a rich taste" and target proposition 2 "The light texture of chocolate cakes is produced by the number of eggs". Third, there are chains of propositions that connect target propositions. For example, proposition 8 "Lemon pie has a light texture" and proposition 9 "Whipped cream on pie is good" together form a bridge between target propositions 3 and 4.

In the ten protocols analyzed, the five from the high linkage passage showed an average of 4.4 looping propositions while the five from the medium linkage passage showed an average of 2.0 looping propositions. These numbers probably underestimate the number of alternate retrieval pathways that are available since the instructions for the scaling task did not encourage the generation of looping propositions. Thus, the high prior knowledge passage showed a greater number of looping propositions and this finding suggests a greater availability of alternate retrieval pathways as a function of prior knowledge.

Our notion is that these available pathways serve a useful function when attempts to directly retrieve passage information fail. For example, if a subject recalls "Cakes made from German cocoas often have a rich taste" but blocks on the next proposition from the passage, he or she may think

"I like the rich taste of eggs" and this thinking of the idea of eggs may cue the retrieval of the proposition that previously could not be recalled.

Conclusion

We have presented evidence that prior knowledge plays a role in the retrieval of information from long term memory. Explanations of this in terms of greater original learning, greater rehearsal, greater word frequency, or higher images values have been discounted. There was consistent support, however, for an alternate retrieval paths explanation. Subjects' retrospective reports were filled with links to prior knowledge, many of their errors appeared to include partial retrieval of propositions, and the prior knowledge structures surrounding higher prior knowledge passages have more alternate retrieval pathways.

Educational Implications

These data can be taken as support for the old educational homily "Relate the new to the known." However, they shed a new light on this homily. Generally, people think that relating new to known facilitates original learning, which indeed it does. However, these data show that relating new to known facilitates retrieval as well. That is, even when two sets of knowledge are equally reproduceable immediately after learning, it is the knowledge that was related to prior knowledge that will survive over time. Thus teachers who compensate for a discrepancy between the material being taught and the learner's prior knowledge by a form of drill are fooling themselves if they think that the compensation will be a permanent one.

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Table 1

Sample Set of Passages Varying in Linkage

while Maintaining Constant Syntax

High Linkage: Henry James

Henry James wrote historical novels.

Many novels described states of mind produced by human actions.

The setting was often in northern England.

Portrait is one of James' novels.

It discusses the states of mind produced by human actions.

The main character in the novel is an American woman in old Europe.

Medium Linkage: Thomas Gray

Thomas Gray created eloquent verse.

Many verses enumerated truisms of the Divine romanticized in meditative bliss.

The philosophy was often of heartfelt action.

"Elegy" is typical of Gray's verse.

It presents truisms of the Divine romanticized with meditative bliss.

The subject matter in the verse is the universal dignity in common mortality.

Low Linkage: Wolfrom von Eschenbach

Wolfrom von Eschenbach composed Homeric Epics.

Many epics elucidated the quest for the Grail concomitant with quotidian chivalry.

The schemata was often from Wartburgian annals.

Parzival is exemplary of Eschenbach's epics.

It delineates the quest for the Grail concomitant with quotidian chivalry.

The trenchant protagonist in the epic is a guileless novitiate in consecrated indenture.

Table 2

Types and Topics of the 27 Passages Used in Study 1

Factual		
Henry James	Washington D.C.	Governor Smith
Thomas Gray	Stockholm	Emperor Hollingshead
Wolfram von Eschenbach	Acera	Premier Chang
Conceptual		
Piano	AA Quality Eggs	German Chocolate Cakes
Fire	Superior Goldfish	Zinc Aluminum Alloys
System	Cum Laude Theses	Organic Halogen Amalgamations
Narrative		
Carol in Middle School	Nancy at School	Susan in a Race
Eric, a Medical Student	Sigunde on a Ship	Raoul in his Studio
Leatha, a Rock Climbing Student	Babanam in a Garden	Francois in Court

Table 3

Mean Propositional Recall as a Function of Linkage

	Study 1*	Study 2**
High	1.85	2.60
Med.	1.04	1.83
Low	1.19	not included

*Above average students. Adjusted for rehearsal, 4 week retention interval

**Average students, controlled for rehearsal, 1 week retention interval

Table 4

Linkage Values for the Four Passages Used in Study 2

	High Linkage	Medium Linkage
Narrative	Henry James -- 23.63	Thomas Gray -- 17.06
Factual	Chocolate Cakes -- 23.71	Zinc Alloys -- 16.73

Table 5

Multiple Regressions of Linkage and Images on Residual Recall

(Effects due to Retrieval have been Removed)

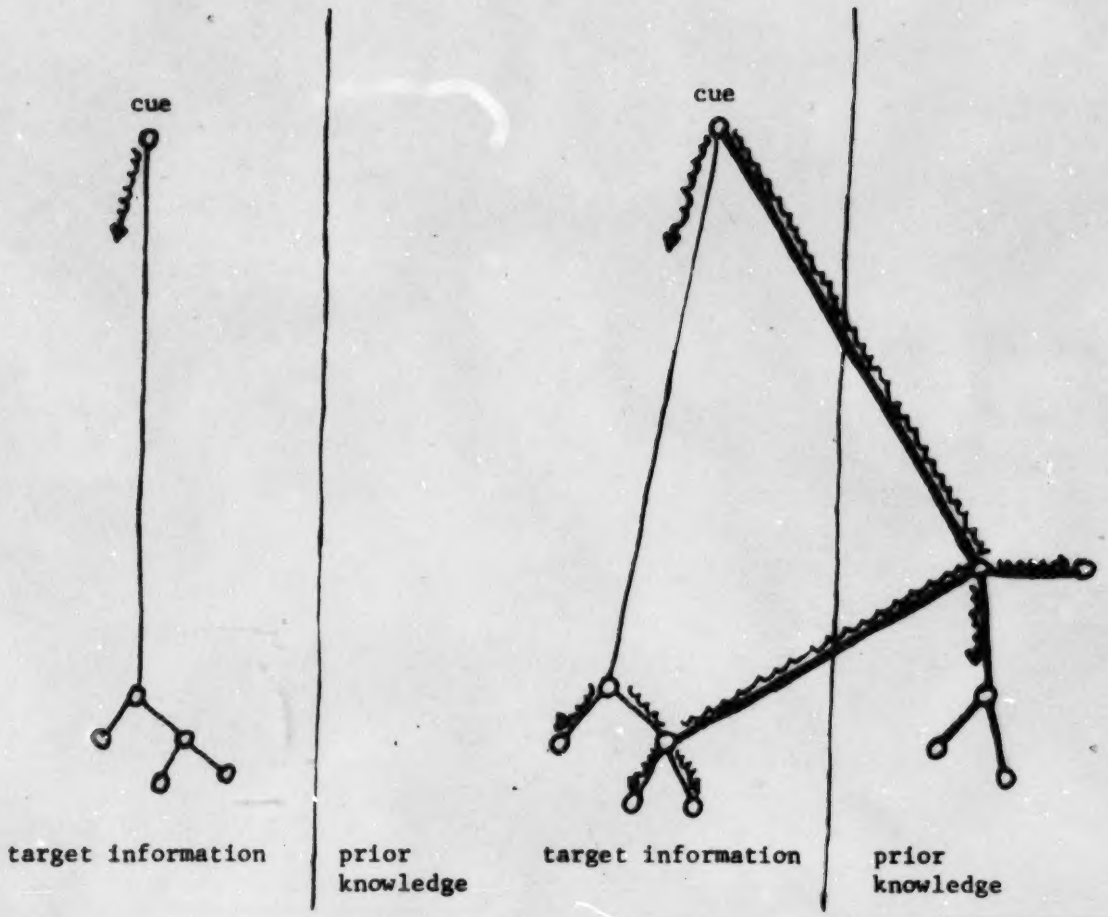
Variable in Order of Being Entered	Multiple R	R^2	R^2 Change
Linkage	.52	.27	.27
Images	.54	.29	.02
Images	.50	.25	.25
Linkage	.54	.29	.04

Table 6

Attributes of Passages Used in Study 3

Passage Title	Linkage Score	Images Score
Sigunde	15.79	3.13
German Chocolate Cakes	23.71	3.02
Zinc Aluminum Alloys	16.73	1.83

Figure 1



A schematic representation of spread-of-activation (squiggly line) in low (A) and high (B) prior knowledge conditions. With low prior knowledge and a weak link from the cue to the target information retrieval attempts fail. Direct retrieval attempts also fail with high prior knowledge but the spread-of-activation to a strong prior knowledge link leads indirectly to activation of the target information.

Table 7

The Propositions Represented in Figure 2

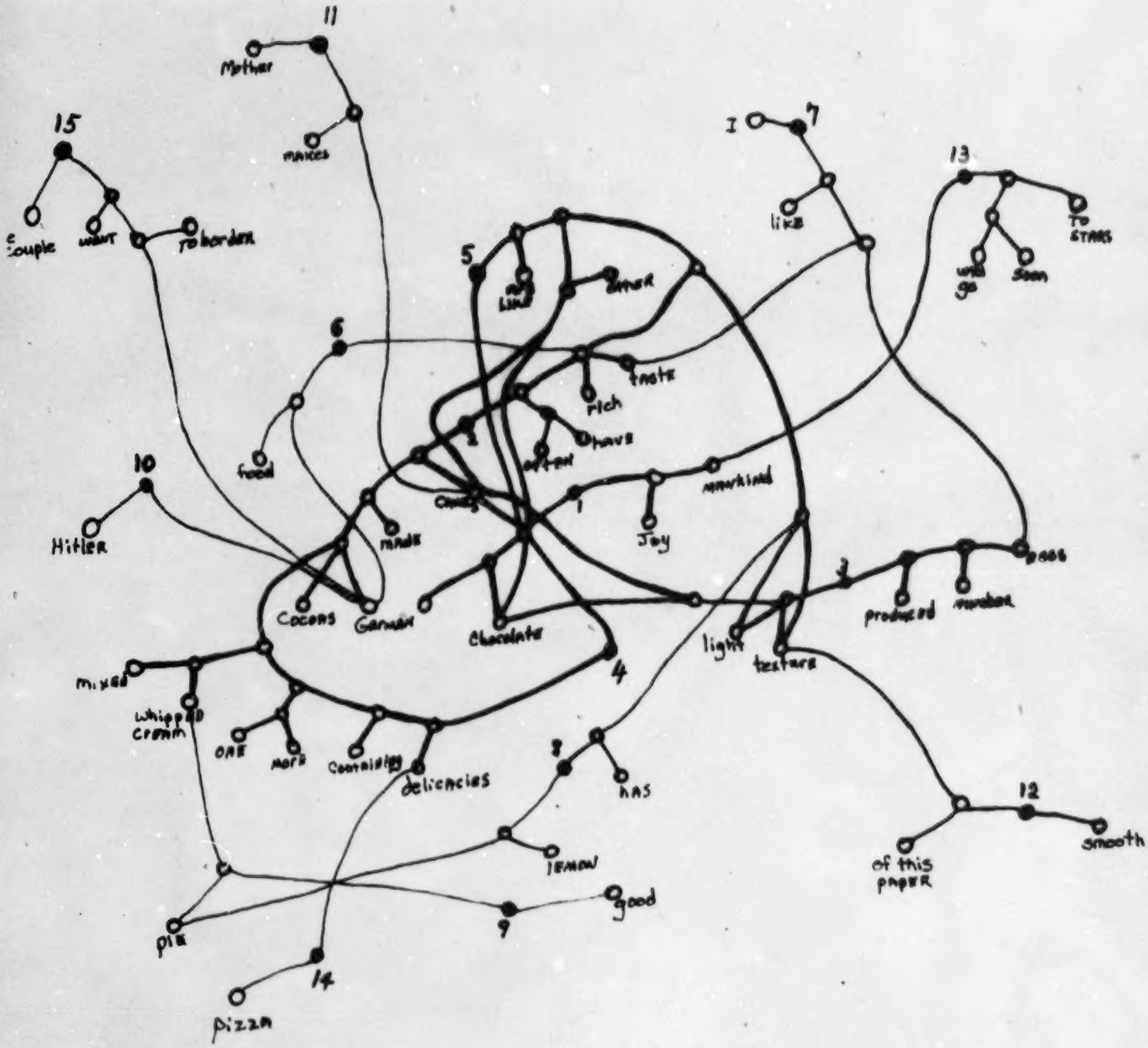
Target Propositions

1. German chocolate cakes are a joy to mankind.
2. Cakes made with German cocoas often have a rich taste.
3. The light texture of chocolate cakes is produced by the number of eggs.
4. German chocolate cakes are delicacies containing one or more of the German cocoas mixed with shipped cream.
5. In their rich taste and light texture, they are much like other chocolate cakes.

Surrounding Propositions

6. German food is rich.
7. I like the taste of eggs.
8. Lemon pie has a light texture.
9. Whipped cream on pie is good.
10. Hitler was German.
11. Mother makes cakes.
12. The texture of this paper is smooth.
13. Mankind will go soon to the stars.
14. Pizzas are delicacies.
15. The couple went to the German border.

Figure 2



Typical looping propositions and other propositions generated for the German Chocolate Cakes passage.

See Table 7 for a translation.